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ACOUSTIC PERFORMANCE OF THE A/M32A-52 EXHAUST MUFFLER (MODIFIED--ETC(U)
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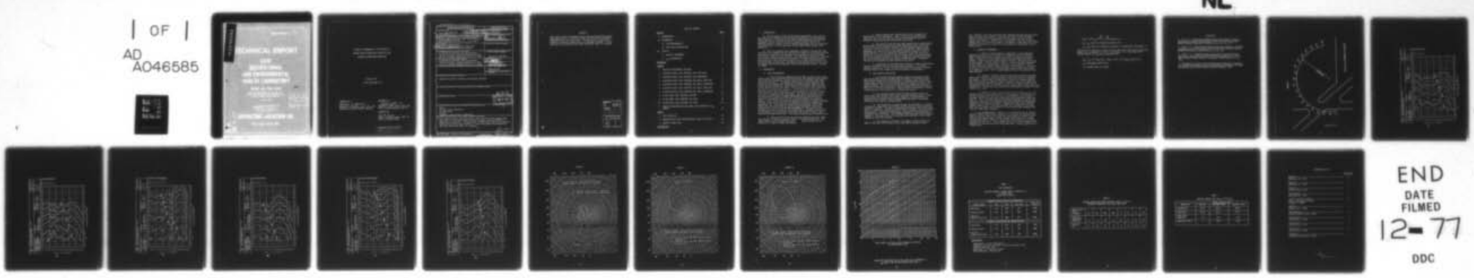

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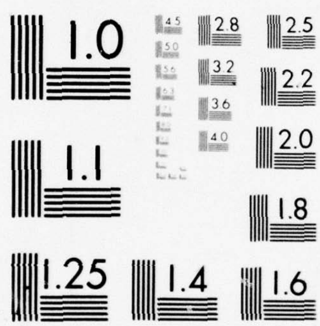

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

Report Number 77-5

TECHNICAL REPORT

USAF OCCUPATIONAL AND ENVIRONMENTAL HEALTH LABORATORY

BROOKS AFB, TEXAS 78235

ACOUSTIC PERFORMANCE OF THE A/M32A-52
EXHAUST MUFFLER (MODIFIED) DURING KC-135A
AIRCRAFT GROUND RUNUP OPERATION

October 1977

OPERATING LOCATION AA

KELLY AFB, TEXAS 78241

ACOUSTIC PERFORMANCE OF THE A/M32A-52 EXHAUST MUFFLER (MODIFIED) DURING KC-135A AIRCRAFT GROUND RUNUP OPERATION

October 1977

OL AA USAF OEHL 77-5

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
OL AA USAF OEHL-77-5

2. GOVT ACCESSION NO.
(14) OEHL-OL AA-77-5

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
(6) ACOUSTIC PERFORMANCE OF THE A/M32A-52 EXHAUST MUFFLER (MODIFIED) DURING KC-135A AIRCRAFT GROUND RUNUP OPERATION.

5. TYPE OF REPORT & PERIOD COVERED
(9) TECHNICAL REP[redacted]T.,

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
(10) NICHOLAS A. FARINACCI Capt, USAF, BSC
Consulting Bioenvironmental Engineer

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
OL AA USAF Occupational and Environmental Health Laboratory, Aerospace Medical Division, Air Force Systems Command, Kelly AFB TX 78241

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
Special Project 77-4

11. CONTROLLING OFFICE NAME AND ADDRESS
OL AA USAF Occupational and Environmental Health Laboratory, Aerospace Medical Division, Air Force Systems Command, Kelly AFB TX 78241

12. REPORT DATE
(11) Oct[redacted]77

13. NUMBER OF PAGES
(12) 24p.

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Noise
Aircraft noise suppressors
Aircraft noise
KC-135A
A/M32A-52 Exhaust Muffler (Modified)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents processed acoustic data acquired during ground runup operations on a KC-135A aircraft with and without a modified A/M32A-52 engine noise suppressor. The data show a significant reduction in acoustic power levels at high power settings. A short discussion for determining day-night equivalent levels is included.

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ABSTRACT

This report presents processed acoustic data acquired during ground runup operations on a KC-135A aircraft with and without a modified A/M32A-52 engine noise suppressor. The data show a significant reduction in acoustic power levels at high power settings. A short discussion for determining day-night equivalent levels is included.

TABLE OF CONTENTS

I. INTRODUCTION:

A. At the request of the National Guard Bureau/DEM a joint effort was conducted by personnel from OL AA USAF Occupational and Environmental Health Laboratory, Kelly AFB TX and 6570 Aerospace Medical Research Laboratory/BBE, Wright-Patterson AFB OH to acquire acoustic data on the A/M32A-52 Muffler, Exhaust, Aircraft Ground Runup (Modified) for evaluating the effectiveness of this suppressor during single engine ground runup operations.

B. This is a portable type suppressor, originally designed for use by Tactical Air Command (TAC) on the J57-P-21 engines, and has been modified according to specifications developed by the US Navy for use with their F-8 aircraft, which also use the J57. The modification consists of replacing the original colander with one fabricated of 1/4-inch cold-rolled steel, perforated with 1/4-inch diameter holes so as to remove approximately 30% of the colander surface area. The modification drawings are on file at the 126 Aerial Refueling Wing (ANG)/MA, O'Hare International Airport, Chicago IL 60666.

II. METHODOLOGY:

A. FIELD MEASUREMENTS:

1. Far-field noise produced by a KC-135A aircraft during single engine ground runup operations with and without the suppressor was acquired at 19 locations spaced at 10 degree intervals on a 100 meter (328 feet) semicircle (Figure 1). The center of the semicircle was located on the ground directly beneath the intersection of the aircraft centerline and a plane passing through the exhaust nozzle of the muffler when installed on the inboard engine (#3 engine). The exhaust plane of this same engine was used for unsuppressed operation. The aircraft was situated on a black-top apron, while measurement locations were over concrete surfaces; a few (0 to 20 degrees) were over grass. The radius of the semicircle was such to assure that the measurements would be in the acoustic far-field where the sound wave fronts spherically diverge and the noise source is considered a point source. In the far-field, the radiation pattern is well formed, allowing extrapolation of data to greater distances from the source when accounting for geometric dispersion, atmospheric absorption, etc. There were no sound reflecting surfaces within 1000 feet of the aircraft except for ground support equipment, which were positioned so as not to disturb the measurements. The semicircle was oriented such that the nose of the aircraft was at 0 degrees and the tail at 180 degrees, and was placed on the same side of the aircraft (right side) as the engine under test. The aircraft heading was 260 degrees true.

2. Only one side of the aircraft was measured since the radiation pattern is laterally symmetric about the aircraft centerline. Two teams covered the measurement locations, each taking one-half of the semicircle in order to speed data acquisition.

3. Several engine power settings were used to compare the effectiveness of the suppressor. Table 1 lists the engine operating conditions for each power setting used and the average surface meteorological conditions present during data acquisition.

4. The acoustic data were recorded sequentially at each measurement location by the two teams over their respective halves of the semicircle using modified NAGRA IV portable battery-operated magnetic tape recorders. The Bruel & Kjaer (B & K) Type 4133 one-half inch condenser microphone was used with B & K Type 2619 microphone preamplifier and air foam windscreen. Each microphone was mounted on a pole and vertically scanned at a uniform rate from 2 feet to 10 feet above the ground during the 10 second sampling period in order to smooth out interactions between the direct radiated sound and the ground reflected sound. Throughout the scan the microphone was kept pointed at the source.

5. Background noise samples were recorded so these interferences could be eliminated from the test data during analysis. All ground support equipment was turned off during the test and individual sampling was done around local airport activity to minimize interferences.

B. DATA ANALYSIS/PROCESSING:

1. At the 6570 Aerospace Medical Research Laboratory, Biodynamic Environments Branch, Wright-Patterson AFB OH, the recording-playback-analysis system was calibrated over a frequency range of one-third octave bands centered from 25 to 20,000 Hz and corrected to effect a flat system response. These corrections included the response of the microphone and windscreen, accounting for the incidence (perpendicular) of the sound on the microphone diaphragm. Random incidence corrections (instead of perpendicular) were applied to the background samples.

2. The recorded acoustic data was analyzed into one-third octave band sound pressure levels over this same frequency range. These raw data were then processed by digital computer at the Aeronautical Systems Division Computer Center, Wright-Patterson AFB OH, to provide calculated noise data as discussed below.

3. The propagation of sound through the atmosphere is strongly influenced by temperature and relative humidity and to a lesser extent by barometric pressure. Therefore, the data were corrected from field meteorology to standard day meteorology (59°F, 70% rel humidity, and 29.92 in Hg bar pressure). Standard day meteorology represents the average weather conditions found worldwide. The resulting normalized data can be directly compared at the same distance to normalized data obtained at other power settings or from other sources.

4. The accuracy of the data is at least ± 2 dB in the 25 to 5000 Hz one-third octave bands, and ± 3 dB, 6300 to 20,000 Hz bands.

III. RESULTS: The final processed data represent expected average levels based on standard day weather. Data were not taken at the 180 degree position during the two unsuppressed military power runs due to high exhaust flow velocity. Usually this is unimportant since the levels are approximately 20 dB less than those at 170 degrees. Other data were either deleted or corrected to account for the proximity of background or electronic noise.

A. ACOUSTIC PERFORMANCE:

1. Table 2, which presents a comparison of this suppressor performance with Grade III residuals in accordance with MIL-N-83155B (USAF) at 250 feet, military power (dry), and at standard day meteorology, indicates that this suppressor does not meet Grade III specifications. However, acoustic power levels allow for a comparison which may be more useful. They are given in Table 3. Notice that the suppressor is not effective at lower exhaust flow rates such as 80% RPM. But at military power the acoustic power reduction is significant, on the order of 19 dB (re 10^{-12} watt) for military power (dry) at which most engine trim operations occur. This is approximately 1/83 of the original sound power emitted.

2. Figures 2 through 7 show extrapolated far-field A-weighted equal level contours of expected average levels calculated for standard day weather. The contours, presented as a function of angle around and far-field distance (in meters) from the aircraft, are in 5 dB steps with every 10 dB step lined in and labeled. Figures 8 through 10 show the 85 dBA butterfly contours for the 80%, military (dry), and military (wet) runs respectively. For brevity only one-half of the butterfly is shown; distance scaling is in feet.

3. Notice in Figure 8 the reversal of the contours, i.e., the suppressed engine being louder from 0 to 110 degrees. An examination of the 80% suppressed raw data indicates a reinforcement of the levels in the upper one-third octave bands, especially those centered on 2000 and 4000 Hz. This is possibly caused by resonances generated by having the suppressor connected, the suppressor not being designed for maximum performance at low exhaust flow rates. Regardless of the cause, the phenomenon appears only in the lower settings (or is masked in the higher ones) and its impact on the contours is very minimal when compared with those at higher power settings.

B. L_{dn} DETERMINATION: Figure 11 is a chart which can be used to convert these 85 dBA butterfly contours to L_{dn} values for daytime (0700 - 2200 hrs) ground runups only, given the total number of similar engine runups during daytime only, and the average runup duration in seconds. For nighttime (2200 - 0700 hrs) runups only, add 10 dB to the L_{dn} value obtained from the chart. Thus a comparison of the relative impact of the daytime and nighttime operations can be obtained. Total L_{dn} may be calculated from:

$$L_{dn} = 10 \log_{10} (10^{\frac{L_d}{10}} + 10^{\frac{L_n}{10}}), \text{ where} \quad \text{eq. 1}$$

$L_d = L_{dn}$ value for daytime operations, and

$L_n = L_{dn}$ value for nighttime operations, as determined from Figure 11.

Besides being a function of runup duration and time of day that the operation occurs, L_{dn} is dependent on level. Accordingly, if a level other than 85 dBA is used, the L_{dn} may be computed from:

$$L_{dn} = L_A + 10 \log_{10} (N_d + 10N_n) - 49.4 + 10 \log_{10} D, \text{ where} \quad \text{eq. 2}$$

L_A = A-weighted sound level,

D = average runup in seconds.

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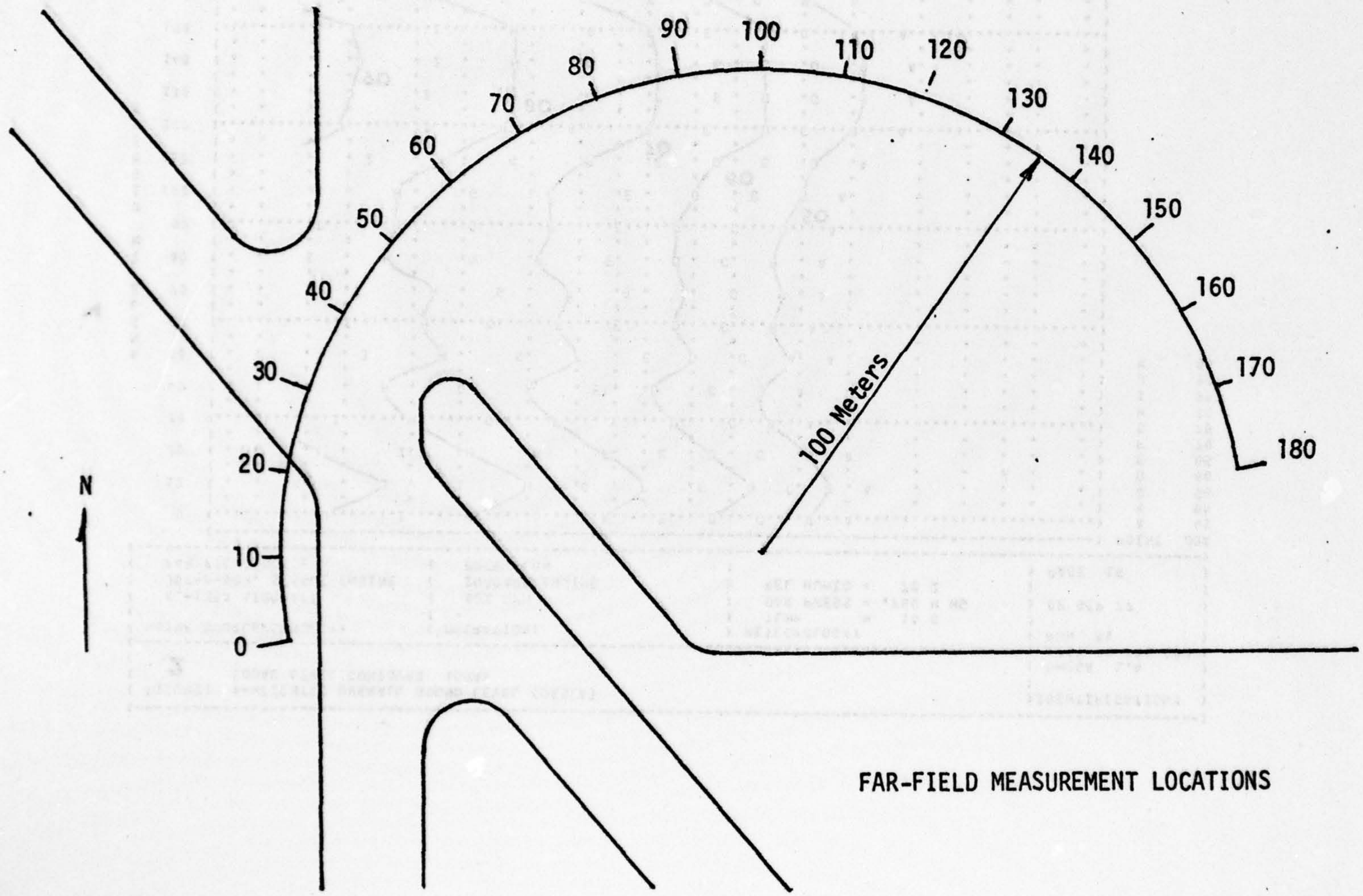
4. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, EPA Report No. 550/9-74-004, US Environmental Protection Agency, 1974.

FIGURE 1



FAR-FIELD MEASUREMENT LOCATIONS

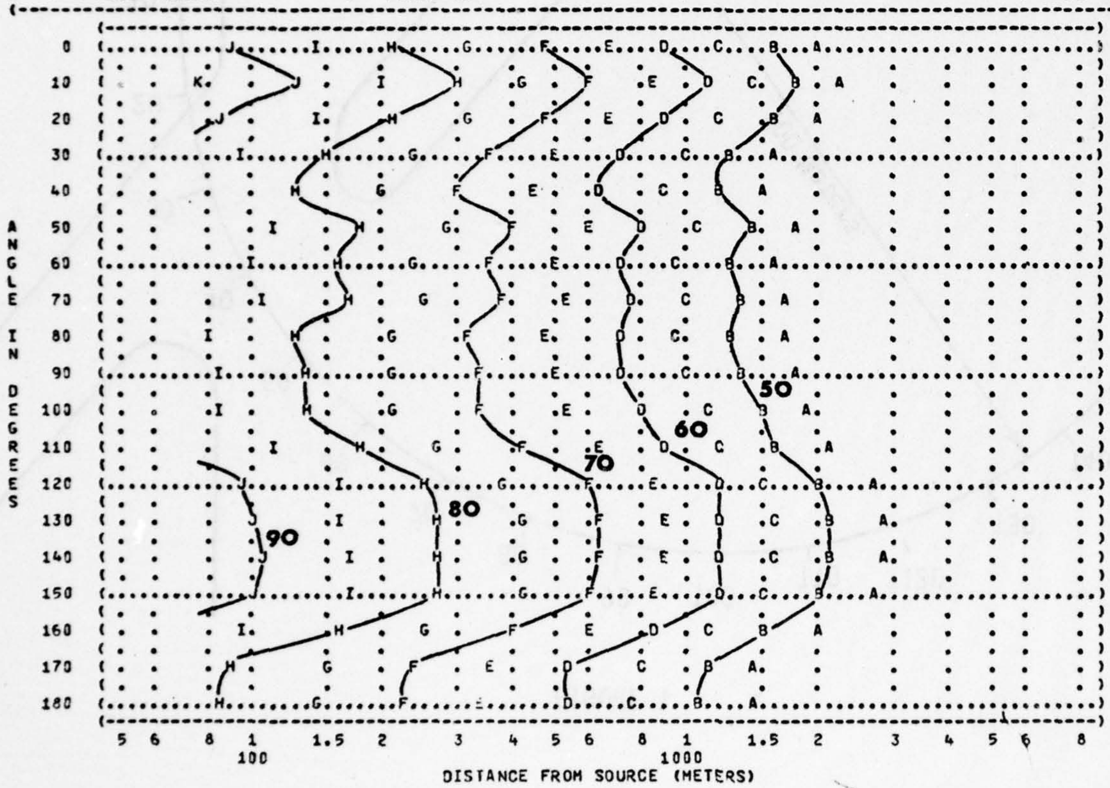
FIGURE: A-WEIGHTED OVERALL SOUND LEVEL (OASLA)
EQUAL LEVEL CONTOURS (DBA)
2

IDENTIFICATION:
OMEGA 1.4
TEST 77-726-002
RUN 01
02 SEP 77
PAGE 15

NOISE SOURCE/SUBJECT:
KC-135A AIRCRAFT
J57-P-59W, SINGLE ENGINE
FAR FIELD NOISE

OPERATION:
80% RPM
INBOARD ENGINE
FREE FLOW

METEOROLOGY:
TEMP = 15 C
BAR PRESS = .760 M HG
REL HUMID = 70 %



POINT	DBA
A	45
B	50
C	55
D	60
E	65
F	70
G	75
H	80
I	85
J	90
K	95

FIGURE: A-WEIGHTED OVERALL SOUND LEVEL (OASLA)
EQUAL LEVEL CONTOURS (DBA)

3

IDENTIFICATION:
OMEGA 1.4
TEST 77-726-001
RUN 01

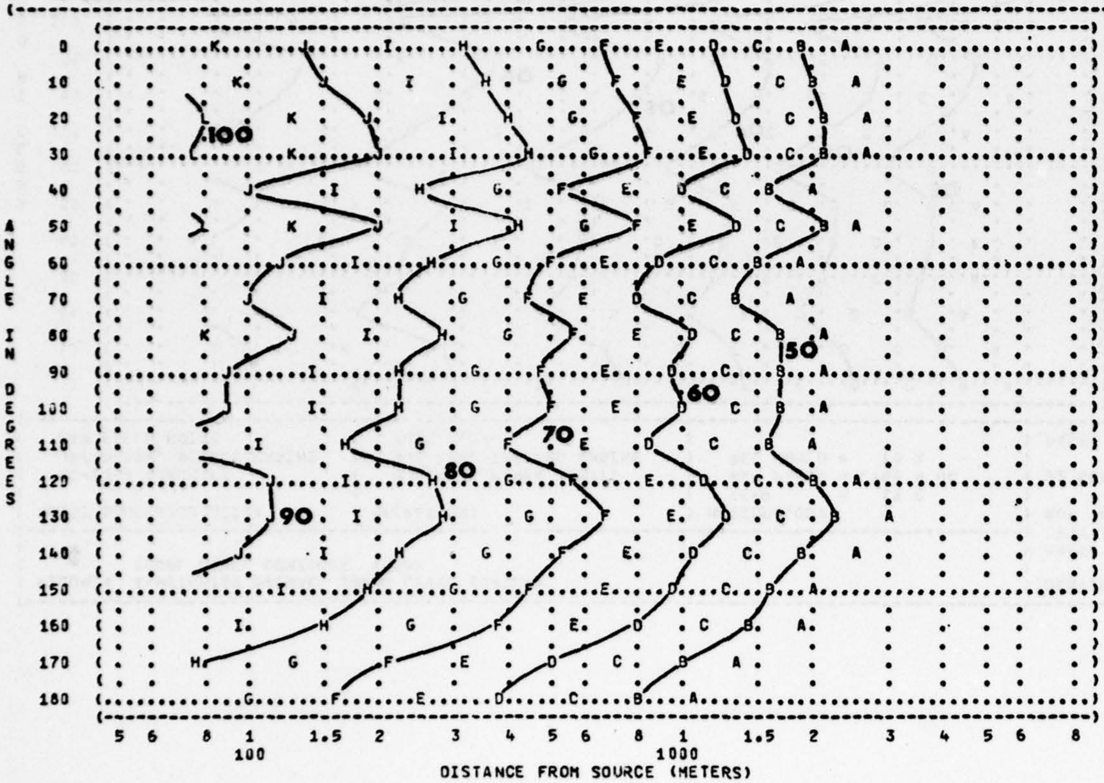
02 SEP 77

PAGE 15

NOISE SOURCE/SUBJECT:
A/M32A-52 MUFFLER,
AIRCRAFT GROUND RUNUP
(MODIFIED) MOUNTED ON
KC-135A AIRCRAFT

OPERATION:
80% RPM
INBOARD ENGINE WITH
SUPPRESSOR MOUNTED

METEOROLOGY:
TEMP = 15 C
BAR PRESS = .760 M HG
REL HUMID = 70 %



POINT	DBA
A	45
B	50
C	55
D	60
E	65
F	70
G	75
H	80
I	85
J	90
K	95
L	100

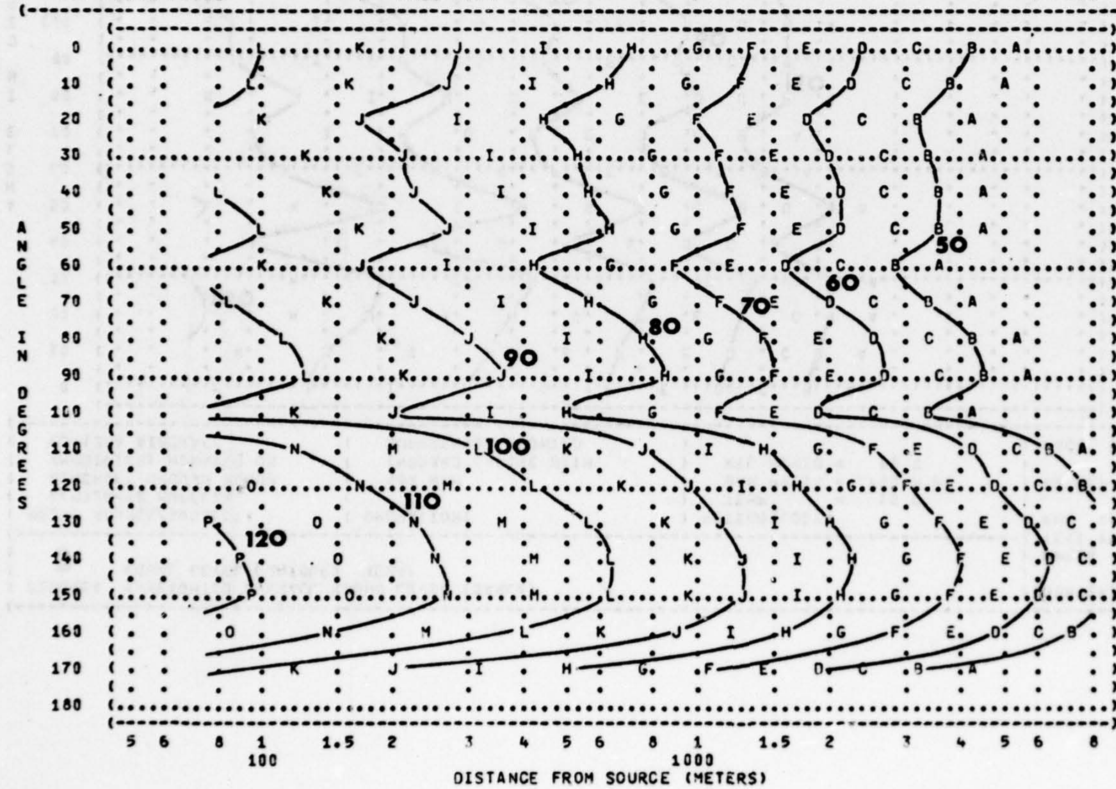
FIGURE: 4 A-WEIGHTED OVERALL SOUND LEVEL (OASLA)
EQUAL LEVEL CONTOURS (DBA)

IDENTIFICATION:
OMEGA 1.4
TEST 77-726-002
RUN 02
02 SEP 77
PAGE 15

NOISE SOURCE/SUBJECT:
KC-135A AIRCRAFT
J57-P-59W, SINGLE ENGINE
FAR FIELD NOISE

OPERATION:
MILITARY POWER (DRY),
95% RPM, INBOARD ENGINE
FREE FLOW

METEOROLOGY:
TEMP = 15 C
BAR PRESS = .760 M HG
REL HUMID = 70 %



POINT	DBA
A	45
B	50
C	55
D	60
E	65
F	70
G	75
H	80
I	85
J	90
K	95
L	100
M	105
N	110
O	115
P	120

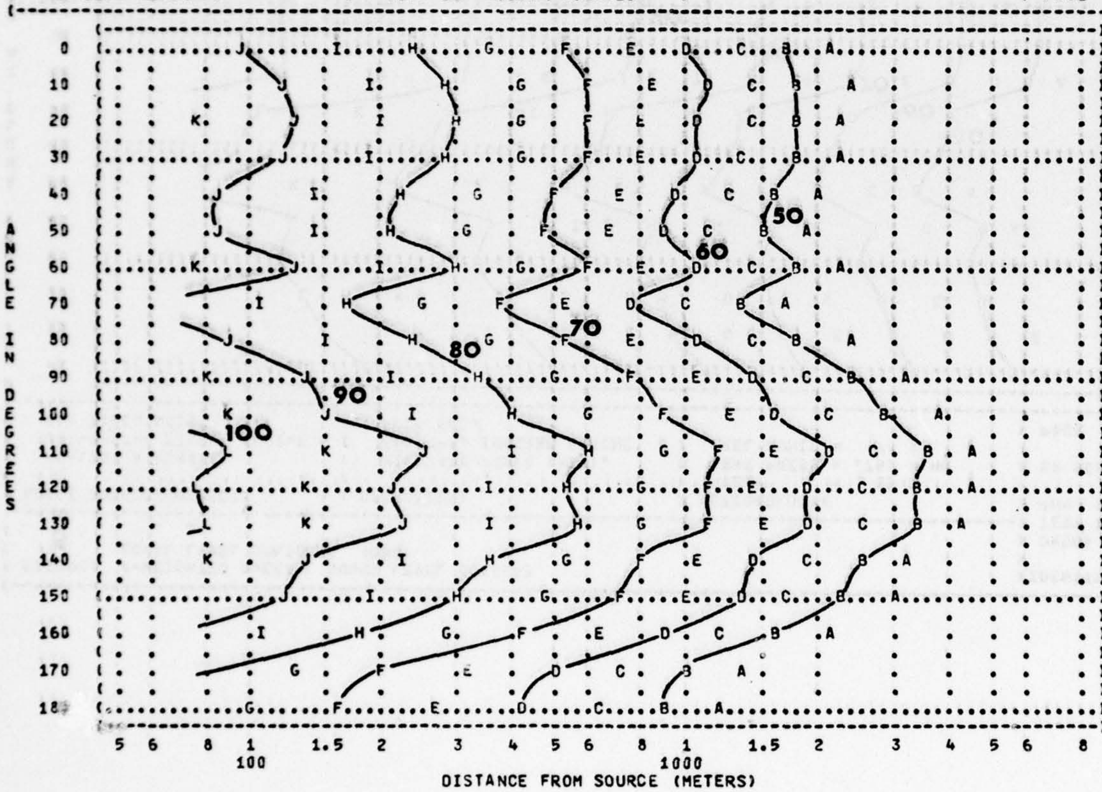
FIGURE: 5 A-WEIGHTED OVERALL SOUND LEVEL (OASLA)
EQUAL LEVEL CONTOURS (DBA)

IDENTIFICATION:
OMEGA 1.4
TEST 77-726-001
RUN 02
02 SEP 77
PAGE 15

NOISE SOURCE/SUBJECT:
A/M32A-52 MUFFLER,
AIRCRAFT GROUND RUNUP
(MODIFIED) MOUNTED ON
KC-135A AIRCRAFT

OPERATION:
MILITARY POWER (DRY),
96% RPM, INBOARD ENGINE
WITH SUPPRESSOR MOUNTED

METEOROLOGY:
TEMP = 15 C
BAR PRESS = .760 M HG
REL HUMID = 70 %



POINT	DBA
A	45
B	50
C	55
D	60
E	65
F	70
G	75
H	80
I	85
J	90
K	95
L	100

FIGURE: 6

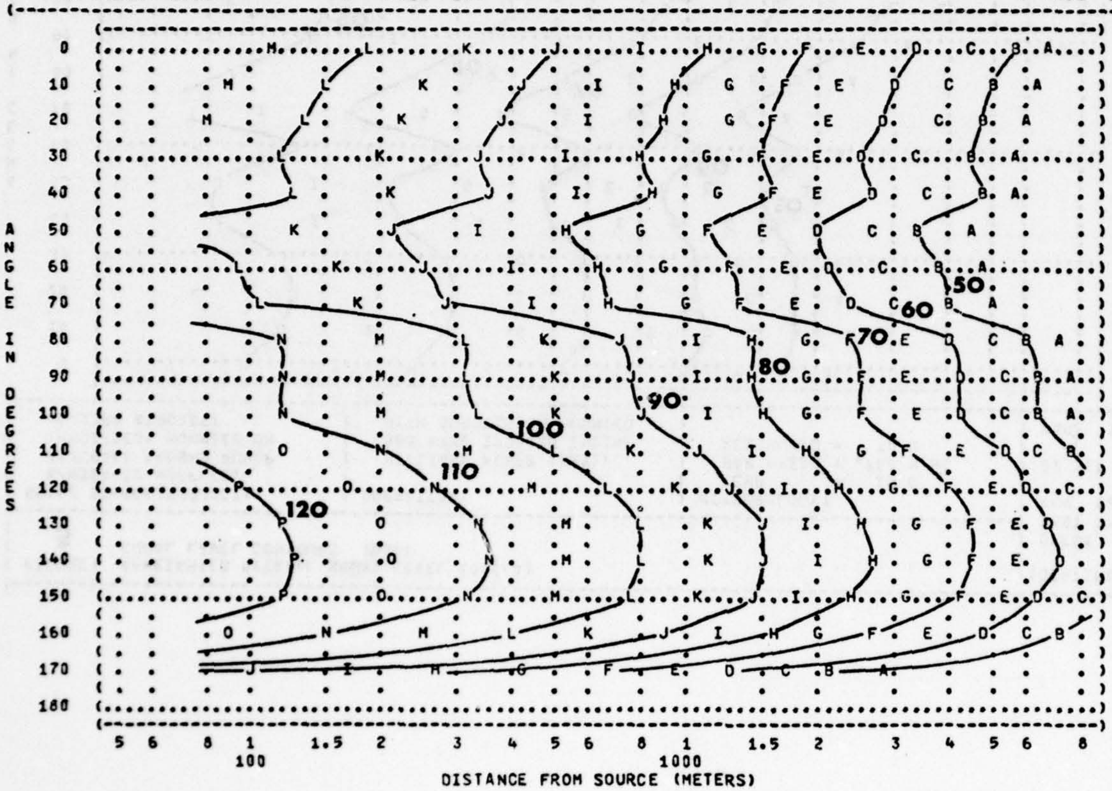
A-WEIGHTED OVERALL SOUND LEVEL (OASLA)
EQUAL LEVEL CONTOURS (DBA)

IDENTIFICATION:
OMEGA 1.4
TEST 77-726-002
RUN 03
02 SEP 77
PAGE 15

NOISE SOURCE/SUBJECT:
KC-135A AIRCRAFT
J57-P-59W, SINGLE ENGINE
FAR FIELD NOISE

OPERATION:
MILITARY POWER (WET),
96% RPM, INBOARD ENGINE
FREE FLOW

METEOROLOGY:
TEMP = 15 C
BAR PRESS = .760 M HG
REL HUMID = 70 %



POINT	DBA
A	45
B	50
C	55
D	60
E	65
F	70
G	75
H	80
I	85
J	90
K	95
L	100
M	105
N	110
O	115
P	120

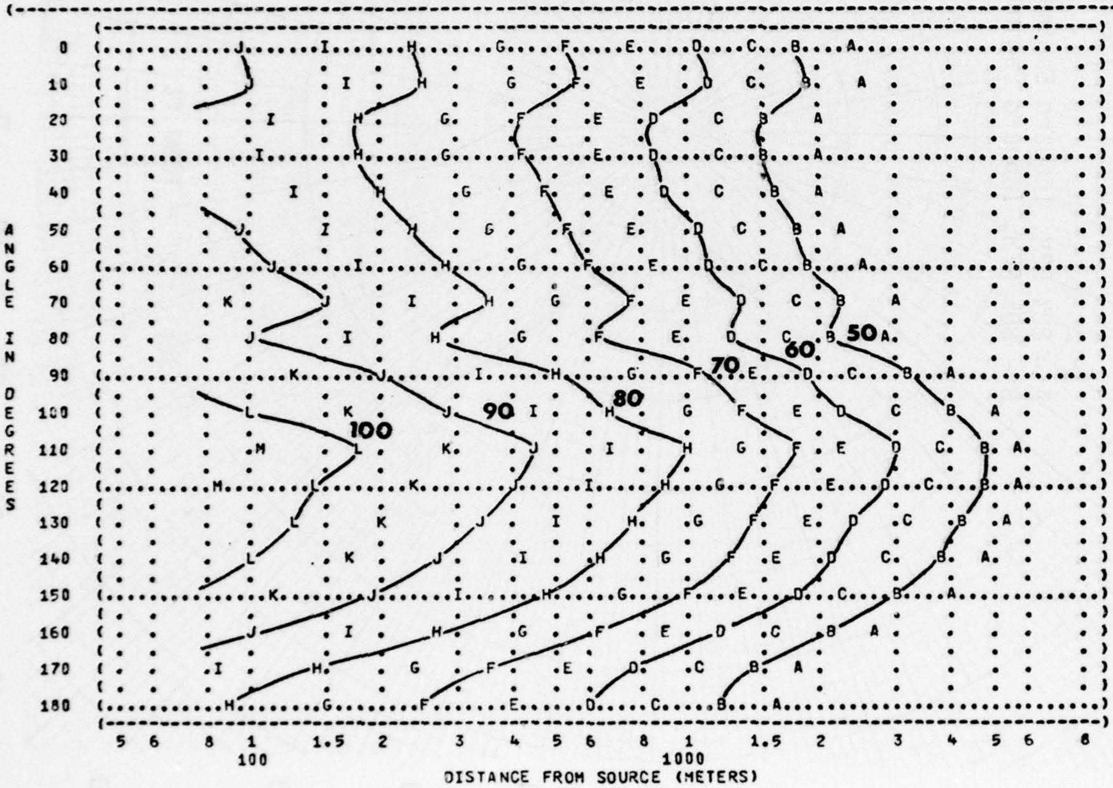
FIGURE: 7 A-WEIGHTED OVERALL SOUND LEVEL (OASLA) EQUAL LEVEL CONTOURS (DBA)

IDENTIFICATION:
OMEGA 1.4
TEST 77-726-001
RUN 03
02 SEP 77
PAGE 15

NOISE SOURCE/SUBJECT:
A/M32A-52 MUFFLER,
AIRCRAFT GROUND RUNUP
(MODIFIED) MOUNTED ON
KC-135A AIRCRAFT

OPERATION:
MILITARY POWER (WET),
96% RPM, INBOARD ENGINE
WITH SUPPRESSOR MOUNTED

METEOROLOGY:
TEMP = 15 C
BAR PRESS = .760 M HG
REL HUMID = 70 %



POINT	DBA
A	45
B	50
C	55
D	60
E	65
F	70
G	75
H	80
I	85
J	90
K	95
L	100
M	105

FIGURE 8

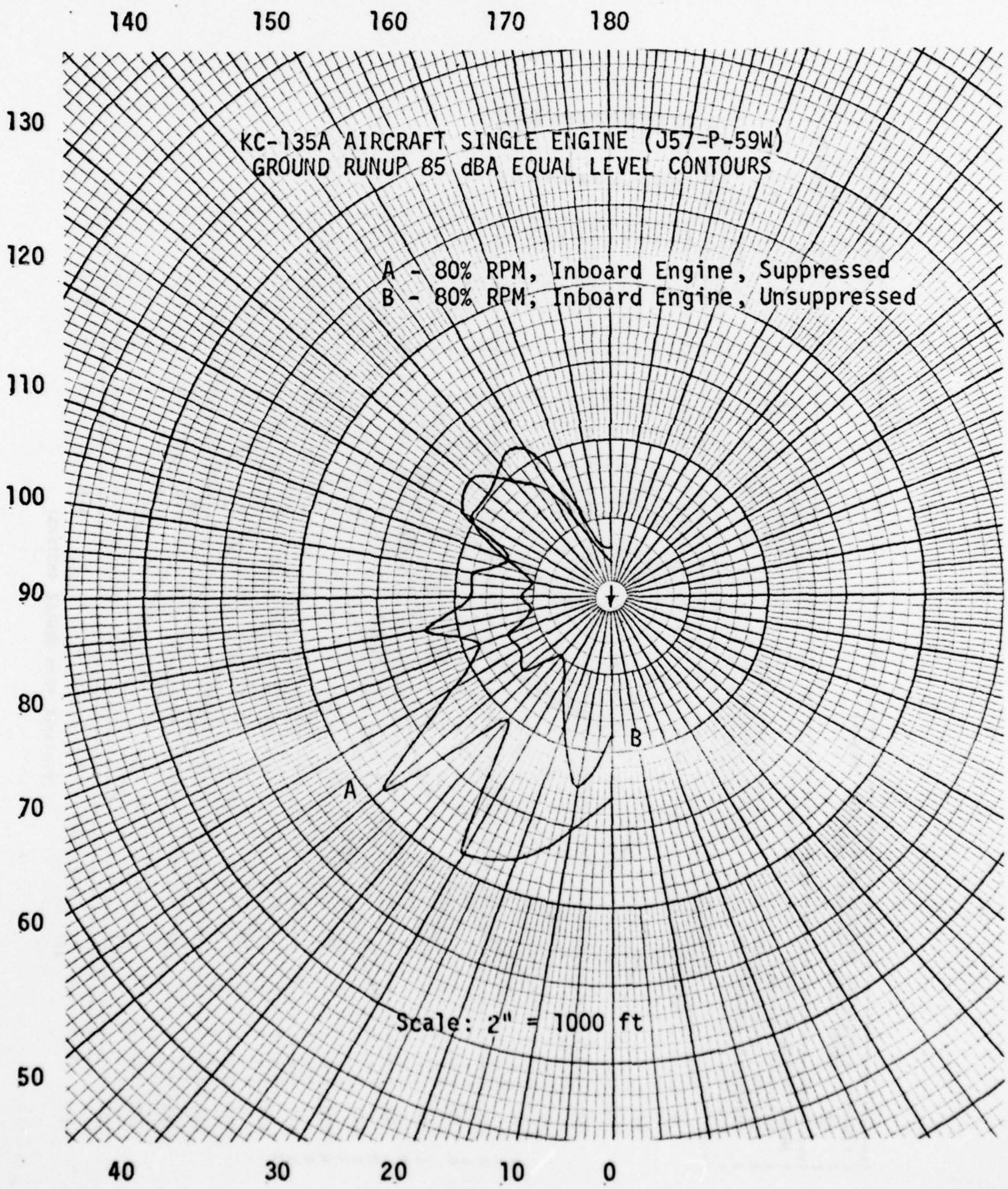

140
150
160
170
180
130
120
110
100
90
80
70
60
50
40
30
20
10
0
KC-135A AIRCRAFT SINGLE ENGINE (J57-P-59W)
GROUND RUNUP 85 dBA EQUAL LEVEL CONTOURS
A - 80% RPM, Inboard Engine, Suppressed
B - 80% RPM, Inboard Engine, Unsuppressed
A
B
Scale: 2" = 1000 ft

FIGURE 9

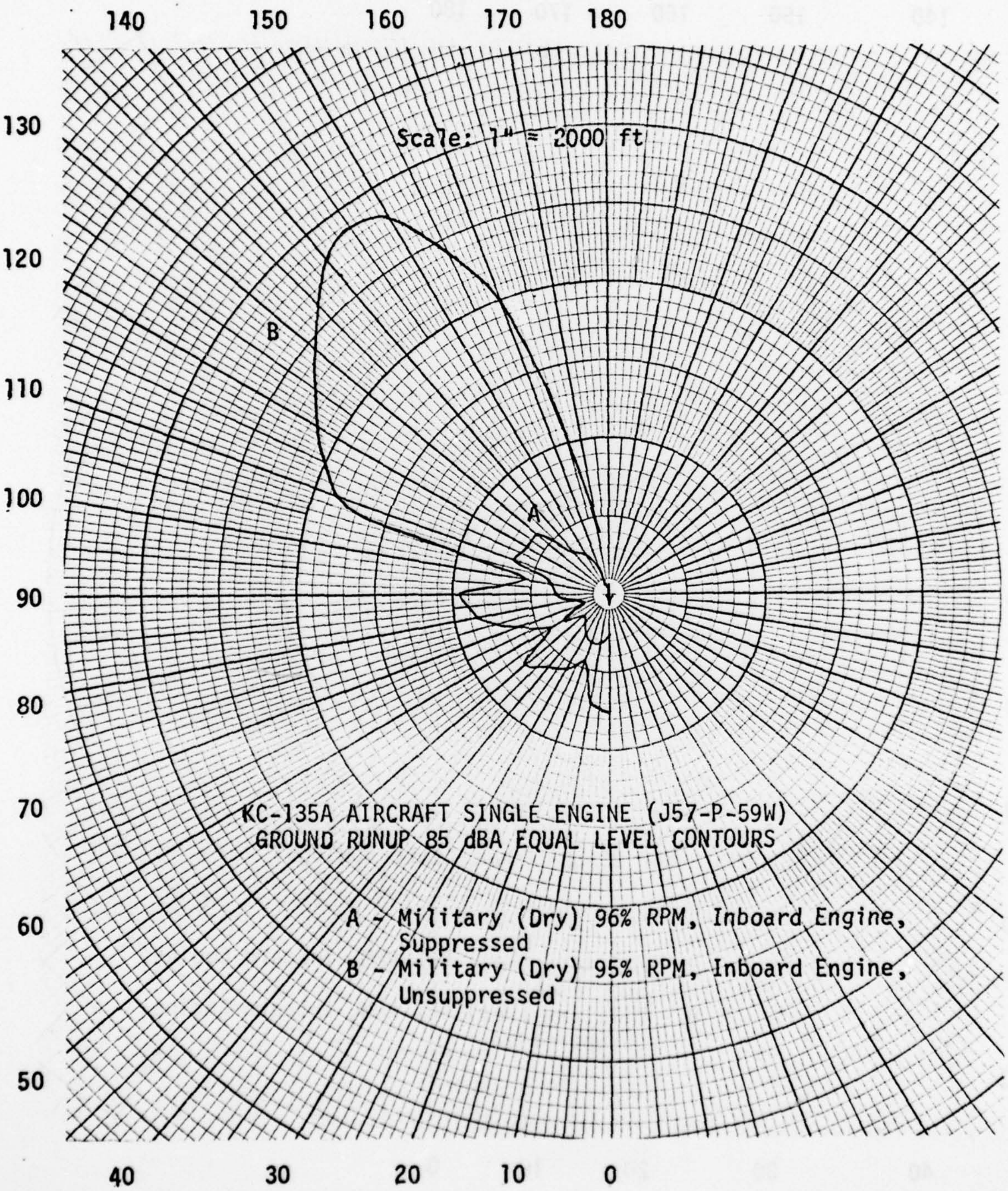
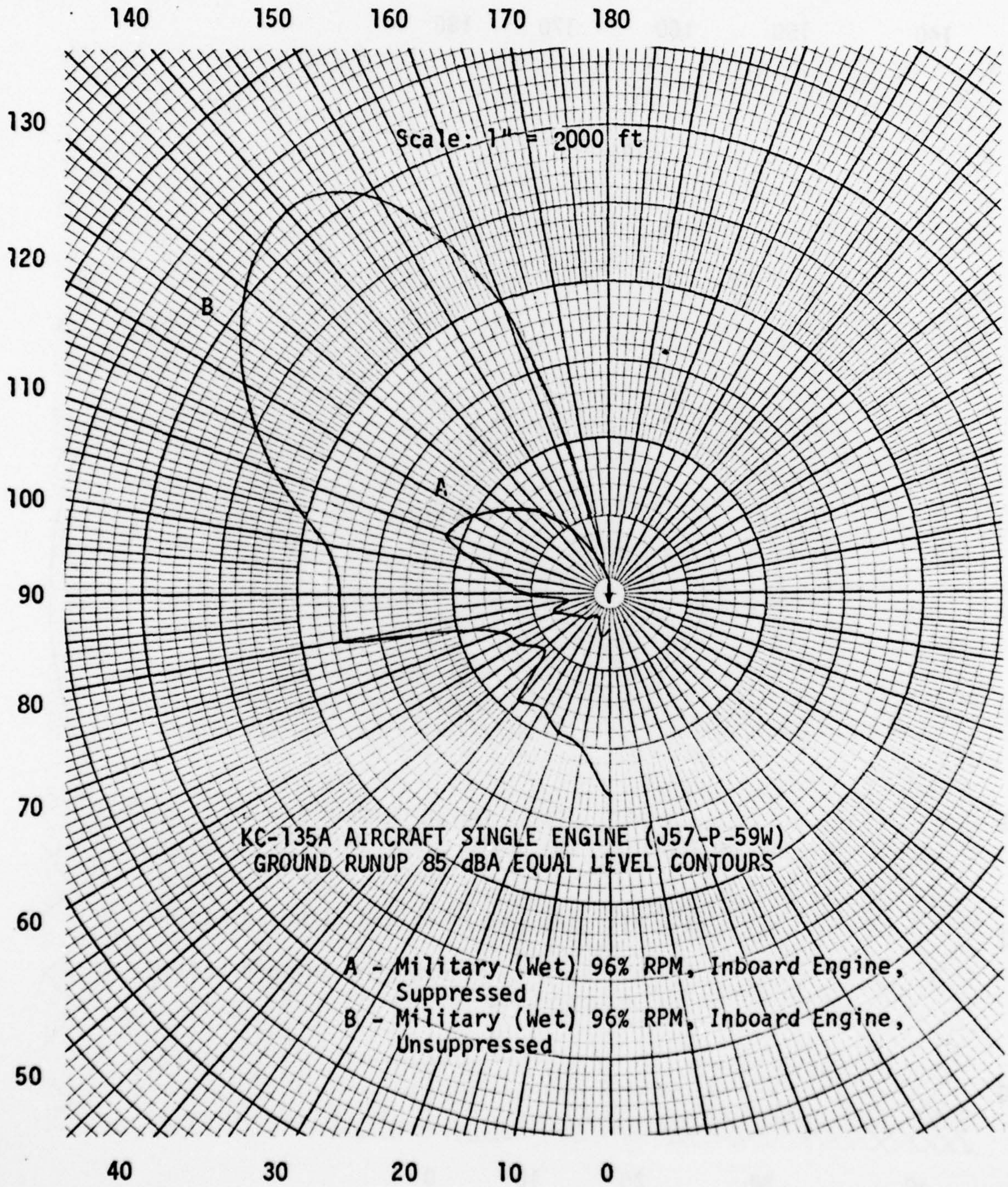

140
150
160
170
180
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Scale: 1" = 2000 ft
B
A
KC-135A AIRCRAFT SINGLE ENGINE (J57-P-59W)
GROUND RUNUP 85 dBA EQUAL LEVEL CONTOURS
A - Military (Dry) 96% RPM, Inboard Engine, Suppressed
B - Military (Dry) 95% RPM, Inboard Engine, Unsuppressed

FIGURE 10


140
150
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170
180
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Scale: 1" = 2000 ft
B
A
KC-135A AIRCRAFT SINGLE ENGINE (J57-P-59W)
GROUND RUNUP 85 dBA EQUAL LEVEL CONTOURS
A - Military (Wet) 96% RPM, Inboard Engine, Suppressed
B - Military (Wet) 96% RPM, Inboard Engine, Unsuppressed

FIGURE 11

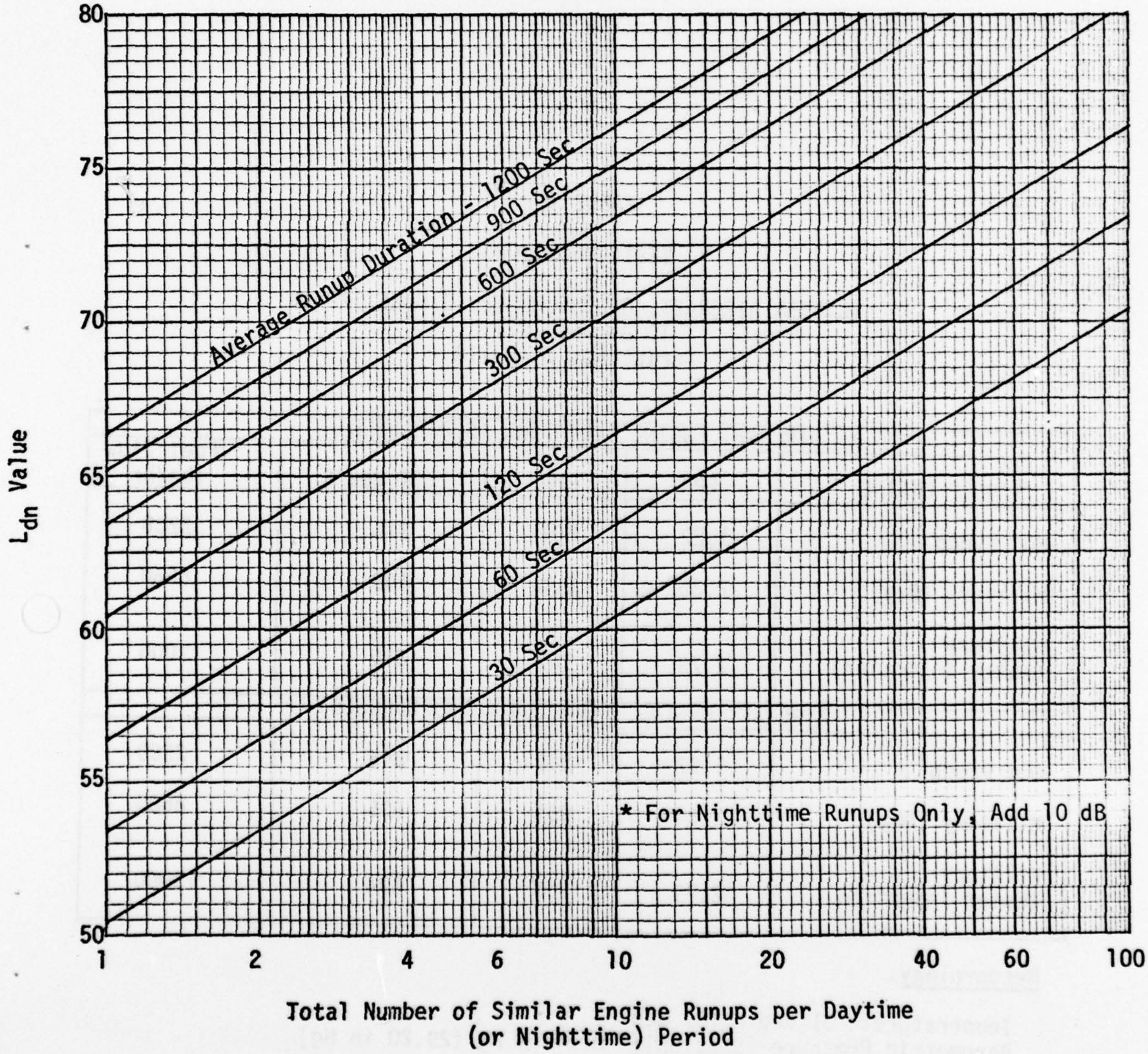

CHART FOR CONVERTING THE 85 dBA EQUAL LEVEL CONTOURS TO L_{dn} VALUES FOR DAYTIME GROUND RUNUPS ONLY *

TABLE 1

TEST CONDITIONS

KC-135A AIRCRAFT, GROUND RUNUP, O'HARE IAP IL
10 August 1977
Serial No. 61-0271A

AIRCRAFT ENGINE OPERATION (SUPPRESSED)				
SINGLE ENGINE	EPR	RPM	EGT deg C	Fuel Flow lbs/hr
80% Runup	1.22	80%	315	2200
Military (Dry)	2.35	96%	608	8550
Military (Water Injection)	2.79	96%	615	13000
AIRCRAFT ENGINE OPERATION (UNSUPPRESSED)				
80% Runup	1.27	80%	345	2350
Military (Dry)	2.34	95%	605	8600
Military (Water Injection)	2.79	96%	624	13000

Meteorology:

Temperature: 31 deg C (87 deg F)
Barometric Pressure (Station): 0.742 m Hg (29.20 in Hg)
Relative Humidity: 52%
Wind Speed: 5.2 m/sec (10 knots)
Wind Direction: 270 deg True

TABLE 2

MAXIMUM OCTAVE BAND SOUND PRESSURE LEVELS AT 250 FT,
STANDARD METEOROLOGY, MILITARY POWER (DRY)

Octave Band Center Frequency	63	125	250	500	1K	2K	4K	8K
Grade III Suppressor Residuals	97	97	96	95	92	91	91	92
Measured SPL	97	100	102	99	97	93	90	83

TABLE 3

ACOUSTIC POWER LEVEL (dB re 10^{-12} Watt)

OPERATION	ENGINE POWER SETTING		
	80% RPM	MILITARY (DRY)	MILITARY (WET)
Unsuppressed	141.9	165.9	169.6
Suppressed	142.0	146.7	152.1
Power Level Reduction	-0.1	19.2	17.5
Reduction Factor	-	1/83	1/56

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